L Number	Hits	Search Text	DB	Time stamp
1	1	("5747878").PN.	USPAT; US-PGPUB	2003/03/11 15:05
2	1	("6033976").PN.	USPAT; US-PGPUB	2003/03/11 15:09
3	1	("5888859").PN.	USPAT; US-PGPUB	2003/03/11 15:11
4	1	("5604365").PN.	USPAT; US-PGPUB	2003/03/11 15:11
5	1	("5604356").PN.	USPAT; US-PGPUB	2003/03/11 15:15
6	1	("4939562").PN.	USPAT; US-PGPUB	2003/03/11 15:16
7	651	(ohmic adj (contact or electrode)) same (Ni or nickel) same (adhesive or adhesion or Ti or Cr or Si or silicon)	USPAT; US-PGPUB	2003/03/11 15:18
8	444	((ohmic adj (contact or electrode)) same (Ni or nickel) same (adhesive or adhesion or Ti or Cr or Si or silicon)) and (Ti or titanium)	USPAT; US-PGPUB	2003/03/11 15:18
9	127	(((ohmic adj (contact or electrode)) same (Ni or nickel) same (adhesive or adhesion or Ti or Cr or Si or silicon)) and (Ti or titanium)) and (compound adj semiconductor)	USPAT; US-PGPUB	2003/03/11 15:19
10	68	((((ohmic adj (contact or electrode)) same (Ni or nickel) same (adhesive or adhesion or Ti or Cr or Si or silicon)) and (Ti or titanium)) and (compound adj semiconductor)) and (Ti with Ni)	USPAT; US-PGPUB	2003/03/11 15:19
11	53	(((((ohmic adj (contact or electrode)) same (Ni or nickel) same (adhesive or adhesion or Ti or Cr or Si or silicon)) and (Ti or titanium)) and (compound adj semiconductor)) and (Ti with Ni)) and @ad<=20000928	USPAT; US-PGPUB	2003/03/11 15:20

enough
spent 1.5 days
3/12/03

L Number	Hits	Search Text	DB	Time stamp
1	918	(ohmic with (contact or electrode)) and ((compound adj semiconductor) same (Ni or ru or v or au or co))	USPAT; US-PGPUB	2003/03/11 10:27
2	84	((ohmic with (contact or electrode)) and ((compound adj semiconductor) same (Ni or ru or v or au or co))) and HBT	USPAT; US-PGPUB	2003/03/11 10:27
3	62	(((ohmic with (contact or electrode)) and ((compound adj semiconductor) same (Ni or ru or v or au or co))) and HBT) and @ad<=20000928	USPAT; US-PGPUB	2003/03/11 10:31
4	52	((((ohmic with (contact or electrode)) and ((compound adj semiconductor) same (Ni or ru or v or au or co))) and HBT) and @ad<=20000928) and (react$3 or alloy$3)	USPAT; US-PGPUB	2003/03/11 10:32

	U	1 [1]	Document ID	Issue Date	Pages	Title	Current OR
1	☐	☒	US 6207976 B1	20010327	33	Semiconductor device with ohmic contacts on compound semiconductor and manufacture thereof	257/192
2	☒	☒	US 6188137 B1	20010213	14	Ohmic electrode structure, semiconductor device including such ohmic electrode structure, and method for producing such semiconductor device	257/769
3	☒	☒	US 6121153 A	20000919	30	Semiconductor device having a regrowth crystal region	438/706
4	☒	☒	US 6037663 A	20000314	5	Ohmic electrode structure for In.sub.x Ga.sub.1-x As layer	257/751
5	☒	☒	US 6033976 A	20000307	16	Ohmic electrode, its fabricating method and semiconductor device	438/602

	Current XRef	Retrieval Classif	Inventor	S	C	P	2	3	4	5	Image Doc. Displayed	PT
1	257/194; 257/195; 257/197; 257/198; 438/602; 438/604; 438/606		Takahashi, Tsuyoshi et al.	☒	☐	☐	☐	☐	☐	☐	US 6207976	☐
2	257/383; 257/76; 257/79; 257/E29.144; 257/E29.189; 257/E29.315		Yagura, Motoji et al.	☐	☐	☐	☐	☐	☐	☐	US 6188137	☐
3	257/192; 257/E27.012; 257/E29.041; 257/E29.116; 257/E29.144; 257/E29.189; 257/E29.249; 257/E29.315; 438/735		Kikkawa, Toshihide	☐	☐	☐	☐	☐	☐	☐	US 6121153	☐
4	257/744; 257/764; 257/767; 257/E29.144		Yagura, Motoji et al.	☐	☐	☐	☐	☐	☐	☐	US 6037663	☐
5	257/E29.144; 438/604; 438/605; 438/606		Murakami, Masanori et al.	☐	☐	☐	☐	☐	☐	☐	US 6033976	☐

	U	1 [1]	Document ID	Issue Date	Pages	Title	Current OR
6	☒	☒	US 5932896 A	19990803	39	Nitride system semiconductor device with oxygen	257/94
7	☒	☒	US 5888859 A	19990330	48	Method of fabricating semiconductor device	438/174
8	☒	☒	US 5818078 A	19981006	31	Semiconductor device having a regrowth crystal region	257/281
9	☒	☒	US 5747878 A	19980505	15	Ohmic electrode, its fabrication method and semiconductor device	257/745
10	☒	☒	US 5682046 A	19971028	27	Heterojunction bipolar semiconductor device and its manufacturing method	257/198
11	☒	☒	US 5604356 A	19970218	30	Superlattice ohmic contact on a compound semiconductor layer	257/17

	Current XRef	Retrieval Classif	Inventor	S	C	P	2	3	4	5	Image Doc. Displayed	PT
6	257/102; 257/103; 257/96; 257/97; 257/E33.03; 257/E33.043; 372/43; 372/44; 372/45		Sugiura, Lisa et al.	☐	☐	☐	☐	☐	☐	☐	US 5932896	☐
7	257/E29.041; 257/E29.127; 257/E29.149; 257/E29.321; 438/167; 438/589; 438/591		Oku, Tomoki et al.	☐	☐	☐	☐	☐	☐	☐	US 5888859	☐
8	257/280; 257/E27.012; 257/E29.041; 257/E29.116; 257/E29.144; 257/E29.189; 257/E29.249; 257/E29.315		Makiyama, Kozo et al.	☐	☐	☐	☐	☐	☐	☐	US 5818078	☐
9	257/743; 257/750; 257/763; 257/766; 257/768; 257/E29.144		Murakami, Masanori et al.	☐	☐	☐	☐	☐	☐	☐	US 5747878	☐
10	257/631; 257/636; 257/E29.189		Takahashi, Tsuyoshi et al.	☐	☐	☐	☐	☐	☐	☐	US 5682046	☐
11	257/191; 257/22; 257/25; 257/E29.144		Shiraishi, Yasushi	☐	☐	☐	☐	☐	☐	☐	US 5604356	☐

	U	1 [1]	Document ID	Issue Date	Pages	Title	Current OR
12	☒	☒	US 5412249 A	19950502	14	Semiconductor device having layered electrode	257/745
13	☒	☒	US 4939562 A	19900703	13	Heterojunction bipolar transistors and method of manufacture	257/198

	Current XRef	Retrieval Classif	Inventor	S	C	P	2	3	4	5	Image Doc. Displayed	PT
12	257/432; 257/466; 257/763; 257/764; 257/766; 257/E29.144; 257/E31.125		Hyugaji, Masahiko et al.	☐	☐	☐	☐	☐	☐	☐	US 5412249	☐
13	257/201; 257/523; 257/564; 257/586; 257/609; 257/615; 257/E29.189; 257/E29.193		Adlerstein, Michael G.	☐	☐	☐	☐	☐	☐	☐	US 4939562	☐

US-PAT-NO: 6316792

DOCUMENT-IDENTIFIER: US 6316792 B1

TITLE: Compound semiconductor light emitter and a method for manufacturing the same

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Current spreading layer 14 may include a second agent layer (not shown) formed on transparent conductive layer 15 below anode 17. The second agent layer forms a good **ohmic contact** to anode 17 and improves the **adhesion** to anode 17. The second agent layer is made from a metal such as **Ni**, Mo, **Ti**, W, **Cr** or an alloy thereof and has a thickness of less than about 100 nanometers. It is preferable that the thickness of the second agent layer is about 20 nanometers.

FIGS. 2(A)-2(D) are cross sectional views which illustrate a method of manufacturing the device shown in FIG. 1(A). As shown in FIG. 2(A), a thin GaN buffer layer 3 and an N-type GaN layer 5 (doped with silicon, for example) are grown continuously on a sapphire substrate 1 using molecular beam epitaxy (MBE). A P-type GaN layer 7 (doped with magnesium, for example) is then grown on N-type GaN layer 5 by MBE. With reference to FIG. 2(B), a portion of the surface of N-type GaN layer, is exposed by a conventional etching method such as a photo engraving process (PEP). A cathode 9 is formed on the exposed surface portion of N-type GaN layer 5 using a lift-off method after the vacuum evaporation of a metal such as **Ti** or Au or an alloy thereof An annealing process is carried out at a temperature of about 700.degree. C. for about 20 minutes to form an ohmic contact between N-type GaN layer 5 and cathode 9.

A dielectric layer 11 of **silicon** dioxide, for example, having a thickness of

about 100 nanometers is then deposited on the whole surface of the structure of FIG. 2(B) using chemical vapor deposition (CVD) as shown in FIG. 2(C). Dielectric layer 11 is then etched using a conventional photo engraving process to expose a portion of P-type GaN layer 7. With reference to FIG. 2(D), an agent layer 13 is formed on the exposed portion of P-type GaN layer 7 by the vacuum evaporation of one or more metals, e.g., magnesium having a thickness of about 1 nanometer and **nickel** having a thickness of about 2 nanometers. A transparent conductive layer 15 of ITO having a thickness of about 200 nanometers is formed on the agent layer 13 by RF sputtering. To improve the **ohmic contact,** annealing is then carried out at about 400.degree. C. for about 10 minutes.

An anode 17 of **Ti, Ni,** Au or an alloy thereof is formed on the remaining block of dielectric layer 11 and on a portion of current spreading layer 14. Anode 17 preferably overlaps onto current spreading layer 14 by about 5 micrometers. It is noted that in some instances, the portion of dielectric layer 11 formed on cathode 9 may be removed. In this case, cathode 9 will further include a layer 9a of the material used to form anode 17 (see FIG. 1(A)). Finally, as shown in FIG. 1(B), the sapphire substrate 1 of the light emitting element is glued onto a lead frame 19. Anode 17 and cathode 9 are connected to the ends 21 and 19 of the lead frame, respectively.

An ITO layer cannot be formed directly on P-type GaN layer 7 since ITO includes the N-type dopant tin (Sn). In the present embodiment, agent layer 13 which includes magnesium (Mg) is formed on P-type GaN layer 7. This thickness of agent layer 13 provides 70% of the transmittance for the emitted light. Transparent conductive layer 15 is formed on agent layer 13 to decrease the sheet resistance of current spreading layer 14. Therefore, current spreading layer 14 is in ohmic contact with P-type GaN layer 7 because of agent layer 13. By forming anode 17 mainly on the remaining block of dielectric layer 11, removal of the current spreading layer due to bonding wire tension can be prevented, thereby increasing the manufacturing yield of the light emitting element. The anode 17 and the cathode 9 can be a combination of gold (Au) and one or more metals such as platinum (Pt), **titanium (Ti)**, palladium (Pd) and the

like.

Although GaN is used in this embodiment, it is possible to use In.sub.x Ga.sub.y Al.sub.z N(x+y+z=1, 0.ltoreq.x, y, z.ltoreq.1). In addition, although nickel is used as agent layer 13 in this embodiment, it is possible to use materials which have the same dopant as, the P-type GaN layer 7 such as AuBe or AuMg. Further, agent layer 13 can be a multi-layer arrangement of **Ni**, Au, Zn, **Ti** or alloys thereof to improve adhesion to the agent layer 13. Similarly, transparent conductive layer 15 is not limited to ITO. Other suitable materials for dielectric layer 11 include SiN.sub.x, Al.sub.2 O.sub.3, TiO.sub.2, ZrO.sub.2, Ta.sub.2 O.sub.5, HfO.sub.2, or polyimide.

Buffer layer 33 and contact layer 41 may be formed of other materials such as AlGaAs. Block 43 can be made of dielectric layers such as silicon dioxide, as well as N-type AlGaInP or N-type AlGaAs. Agent layer 45 can also include island-shaped portions as shown in FIG. 4. Although AuZn is used as the agent layer 45 in this embodiment, other materials having the same dopant as P-type GaAs layer 41 may also be used. For example, AuBe, AuMg, AuGe may be used. Agent layer 45 can also have a multi-layer structure of **Ni**, AuZn, **Ti** or alloys thereof to improve adhesion to the agent layer 45. The transparent conductive layer 47 is not limited to ITO.

P-type GaN layer 17 is etched by a conventional photo etching method to expose a portion of the surface of N-type GaN layer 5. A cathode 9 is then formed on the exposed portion of N-type GaN layer 5 using the lift-off method after the vacuum evaporation of a metal such as **titanium (Ti)** or gold (Au). In order to make an ohmic contact between N-type GaN layer 5 and cathode 9, an anneal process is carried out at a temperature of about 700.degree. C. for about 20 minutes. A dielectric layer 11 of, for example, silicon dioxide is deposited on the whole surface using CVD. Dielectric layer 11 is then etched using a conventional photo engraving process to leave a dielectric block portion.

Current spreading layer 14 is formed by the vacuum evaporation of one or more metals. In the embodiment of FIG. 8, current spreading layer 14 includes three

layers. For example., a **nickel (Ni)** layer, a gold (Au) layer, and a **nickel (Ni)** layer are formed successively. Current spreading layer 14 is shaped using the conventional lift-off method. The first layer 14A of current spreading layer 14, having a thickness of about 3 nanometers, is made from **nickel (Ni)** which can make a good **ohmic contact**. The second layer 14B, having a thickness of about 10 nanometers, is made from gold (Au) which has a low sheet resistance. The third layer 14C, having a thickness of about 0.5 nanometer, is made from **nickel (Ni)** which can adhere to protective layer 16. A protective layer 16, formed of **silicon** dioxide and having a thickness of about 220 nanometers, is deposited on current spreading layer 14 using thermal CVD.

An area of protective layer 16 for forming an anode 17 and a region for connection to current spreading layer 14 is removed by conventional photo engraving. Anode 17 is formed on the area from which protective layer 16 has been removed by depositing one or more metals (e.g., **Ti** or Au) and then using the lift-off method. Sapphire substrate 1 of the light emitting element is glued on a lead frame, and anode 17 and cathode 9 are connected to ends of the lead frame.

Current spreading layer 14, cathode 9 and anode 17 can be a combination of gold (Au) and one or more metals such as platinum (Pt), **titanium (Ti)**, paladium (Pd), and nickel (**Ni**). Although current spreading layer 14 of the embodiment of FIG. 8 includes three layers made from **titanium (Ti)**, gold (Au) and nickel (**Ni**), these layers can be made from other materials such **Ni**, Au and **Ti**. In addition, current spreading layer 14 may include more than three layers. Protective layer 16 may be formed of materials other than silicon dioxide such as SiN.sub.x, Al.sub.2 O.sub.3, TiO.sub.2, ZrO.sub.2, Ta.sub.2 O.sub.5, HfO.sub.2 and the like.

US-PAT-NO: 6255129

DOCUMENT-IDENTIFIER: US 6255129 B1

TITLE: Light-emitting diode device and method of manufacturing the same

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According to a third aspect of the present invention, the conductive layer is a light-transmissive layer. As the light-transmissive conductive layer, an indium-tin-oxide layer, a cadmium-tin-oxide layer, a zinc oxide layer, or a thin metal layer, with a thickness in the range from 0.001 .mu.m to 1 .mu.m, made of Au, **Ni,** Pt, Al, Sn, In, Cr, **Ti,** or their alloy, may be used.

Referring to FIG. 4(c), a p-type electrode 409 is formed on the surface of the central p-type layer 406a. The p-type electrode 409 may be made of any metals whose ability to form a p-type **ohmic contact** with the p-type GaN-based compound semiconductor material. For example, the p-type electrode 409 is made of **Ni, Ti,** Al, Au, or their alloy in this embodiment. During the formation of the p-type electrode 409, a transparent contact layer (TCL) 407 with a thickness of 50 .ANG. to 250 .ANG. is preferably inserted between the central p-type layer 406a and the p-type electrode 409 to substantially cover the entire surface of the central p-type layer 406a, thereby simultaneously increasing the light-emitting efficiency and current spreading uniformity of the blue LED 400. The TCL 407 is a light-transmissive, **ohmic contact** layer made of a conductive material, such as Au, **Ni,** Pt, Al, Sn, In, **Cr, Ti,** or their alloy.

Referring to FIG. 4(e), a conductive layer 411 is then coated to directly cover the sidewalls 400a and the bottom surface 400b of the blue LED 400 so as to provide an n-type electrode. At this time, the top side of the blue LED 400 is

protected from contacting the conductive layer 411 by means of the elastic tape 410. As to the material of the conductive layer 411, any metals whose ability to form an n-type ohmic contact with the n-type layer 402 may be used. For example, the conductive layer 411 is made of Au, Al, **Ti,** Cr, or their alloy in this embodiment. The elastic tape 410 is removed to expose the top side of the blue LED 400 after the formation of the conductive layer 411. Since the conductive layer 411 electrically connects with the n-type layer 402 at the sidewalls thereof, the conductive layer 411 is effectively used as an n-type electrode. Therefore the blue LED 400 of the first embodiment according to the present invention is achieved.

During manufacturing of the blue LED 700, all steps are the same as that of manufacturing the blue LED 400 shown in FIGS. 4(a) to 4(e) except for an adhesion layer 701 is formed to cover the sidewalls 400a and the bottom surface 400b of the LED structure 700 before the formation of the conductive layer 411. The adhesion layer 701 is used to enhance the adhesive property between the sidewalls and bottom surface of the insulating substrate 401 and the conductive layer 411. The material of the adhesion layer 701 may be **Ti, Ni,** Al, Cr, Pd, or any metal which can enhance the adhesive property between the sidewalls and bottom surface of the insulating substrate 401 and the conductive layer 411.

In order to achieve the blue LED 800 of the third embodiment, the conductive layer 801 is formed as a light-transmissive layer to allow the transmission of the light generated in the central active layer 404a. As the light-transmissive conductive layer 801, an indium-tin-oxide (ITO) layer, a cadmium-tin-oxide (CTO) layer, a zinc oxide (ZnO) layer, or a thin metal layer, with a thickness in the range from 0.001 .mu.m to 1 .mu.m, made of Au, **Ni,** Pt, Al, Sn, In, Cr, **Ti,** or their alloy, may be used.

9. The method of manufacturing a light-emitting diode device according to claim 1, wherein said conductive layer is a layer selected from a group consisting of an indium-tin-oxide layer, a cadmium-tin-oxide layer, a zinc oxide layer, and a thin metal layer, with a thickness in the range from 0.001 .mu.m to 1 .mu.m, made of a material selected from a group consisting of Au,

Ni, Pt, Al, Sn, In, Cr, **Ti,** and their alloy.

19. The light-emitting diode device according to claim 11, wherein said conductive layer is a layer selected from a group consisting of an indium-tin-oxide layer, a cadmium-tin-oxide layer, a zinc oxide layer, and a thin metal layer, with a thickness in the range from 0.001 .mu.m to 1 .mu.m, made of a material selected from a group consisting of Au, **Ni,** Pt, Al, Sn, In, Cr, **Ti,** and their alloy.

US-PAT-NO: 5917243

DOCUMENT-IDENTIFIER: US 5917243 A

TITLE: Semiconductor device having ohmic electrode and method of manufacturing the same

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The reason for this advantage is as follows. Specifically, according to the present invention, since the **ohmic electrode** is formed of Sn having a low melting point, AuGe having a low melting point and containing Ge serving as an n-type impurity for the GaAs, and **Ni** having satisfactory **adhesion** to the GaAs and having an effect to prevent cohesion of the metal layers forming the electrode, i.e., a so-called ball-up, after the heat treatment, it is possible to satisfactorily form the **ohmic electrode** on the n-type GaAs at the low heat treatment temperature of 300.degree. C. or lower.

FIG. 6 shows another embodiment in which metal thin films are further laminated on the n-side alloyed electrode 4 shown in FIG. 1 and 2. When **Ni**, Sn and AuGe of the n-side electrode 4 are alloyed and then a **Ti** thin film 51, a Pt thin film 52 and a Au thin film 53 are successively laminated on the n-side electrode 4 as shown in FIG. 6, it is possible to obtain the **ohmic electrode** having an excellent **adhesion**. In this arrangement shown in FIG. 6, the thicknesses of the **Ti** thin film 51, the Pt thin film 52, and the Au thin film 53 are set to 5 nm, 10 nm, and 300 nm, respectively.

at least an n-type cladding layer, an active layer, a p-type cladding layer, and a p-type ohmic electrode formed on one main surface or the other main

surface of said n-type GaAs, wherein at least one of said n-type cladding layer and said p-type cladding layer is formed of a II-VI compound semiconductor layer and further comprising a layer of **Ti,** Pt and Au formed on said metal.

at least one layer of a II-VI compound semiconductor on the other main surface of GaAs and further comprising a layer of **Ti;** Pt and Au formed on said metal.